THE NICKEL BULLETIN

A SUMMARY OF CURRENT INFORMATION ON NICKEL

OCTOBER, 1953

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NI-HARD

NI-HARD is a white cast iron alloyed with nickel and chromium to give high hardness and outstanding resistance to abrasion. The structure consists of hard carbide in a matrix rendered martensitic by the nickel content. The wearing faces of heavy castings may be chilled, thus giving a white iron face, backed by grey cast iron where the metal has cooled more slowly.

GRADES

Control of the total carbon content gives two grades of Ni-Hard. High carbon (3·2 to 3·6 per cent.) gives maximum hardness. The lower carbon grade (2·8 to 3·2 per cent.) is employed when service conditions impose the need for maximum possible strength rather than the highest possible hardness. (See notes on Composition.)

CHILL-CASTING

When chill cast, Ni-Hard has greater hardness and strength than when sand cast and, consequently, it has greater resistance to abrasion.

ABRASION RESISTANCE

The remarkable resistance to abrasion under both wet and dry conditions has been repeatedly proved in service. Behaviour in comparison with other metals will depend on type of abrasive and operating conditions.

HEAT RESISTANCE

Ni-Hard retains a high degree of abrasion resistance at elevated temperatures.

MACHINABILITY

Ni-Hard is unmachinable by ordinary methods. Straightforward turning or boring (as required in the making of rolls, pump casings, etc.,) can be carried out by the use of carbide-tipped tools, provided that both the tools and work are supported in rigid equipment; otherwise finishing must be by grinding.

Inserts of grey cast iron or mild steel are sometimes 'cast in', where it is necessary to drill and tap.

GRINDING

Finishing operations are commonly carried out by grinding, for which special grades of wheel have been developed.

WELDING

Welding is not recommended except as a temporary repair. Gas-welding is preferred to arc welding unless preheating can be thoroughly carried out. Ni-Hard is used as a hard facing applied by welding to steel parts.

HEAT-TREATMENT

All Ni-Hard castings benefit from a stress-relieving heat-treatment at 250° to 300°C. Strength is improved without loss of hardness or abrasion-resistance.

DESIGN OF PARTS

Though stronger than unalloyed white iron, Ni-Hard is not ductile and must be adequately supported to withstand heavy impact loading.

COMPOSITION

The composition is varied according to the type of service and the thickness of the casting. As thickness is increased silicon is decreased, nickel and chromium are increased. The level of silicon is controlled to maintain a white fracture.

Lower nickel contents in the range 2·5 to 4·0 are sometimes used to provide modified grades of Ni-Hard.

The proportion of chromium to nickel is usually not greater than 1 to 3. Molybdenum up to 0·4 per cent. is frequently added to improve strength.

The Properties of Ni-Hard Alloyed White Cast Irons

	High Hardness		High Strength	
	Sand Cast	Chill Cast	Sand Cast	Chill Cast
Composition, *per cent.*				
Total Carbon	3·2–3·6		2·8–3·2	
Silicon	0·4–0·7		0·4–0·7	
Manganese	0·3–1·2		0·3–1·2	
Sulphur	0·15 max.		0·15 max.	
Phosphorus	0·3 max.		0·3 max.	
Nickel	3·3–4·8		3·5–5·0	
Chromium	1·2–1·7		1·2–1·7	
Molybdenum	0–0·4		0–0·4	
Physical Properties				
Specific Gravity	7·6–7·8			
Weight, *lb. per cu. in.*	0·275–0·280			
Mean Coefficient of Thermal Expansion, *millionths per °C.*				
10°-100°C.	8·1–9·0			
10°-250°C.	11·5–11·9			
10°-425°C.	12·2–12·8			
Magnetic Response	Magnetic			
Pattern Shrinkage, *in./ft.*	$\frac{5}{32}$–$\frac{1}{4}$			
Mechanical Properties				
Hardness—				
Brinell with Tungsten Carbide Ball	550–650	600–725	500–600	550–650
D.P.N. average of several tests	590–700	640–800	540–640	590–700
Rockwell C scale average of several tests	54–60	57–64	52–57	54–60
Scleroscope „ „ „	72–82	75–90	63–75	72–80
Tensile Strength, *tons/sq. in.*	16–19	18–26	18–22	22–27
Trans. Strength 1·2″ bar 12″ span, *tons/sq. in.*	31–39	35–53	35–43	43–55
Trans. Deflection 1·2″ bar 12″ span, *tons/sq. in.*	0·08–0·11	0·08–0·11	0·10–0·12	0·10–0·12
Izod Impact 1·2″ bar struck 3″ above support, *ft.-lb.*	20–30	25–40	25–35	35–55
Modulus of Elasticity, *millions of lb./sq. in.*	24–26	24–26	24–26	24–26

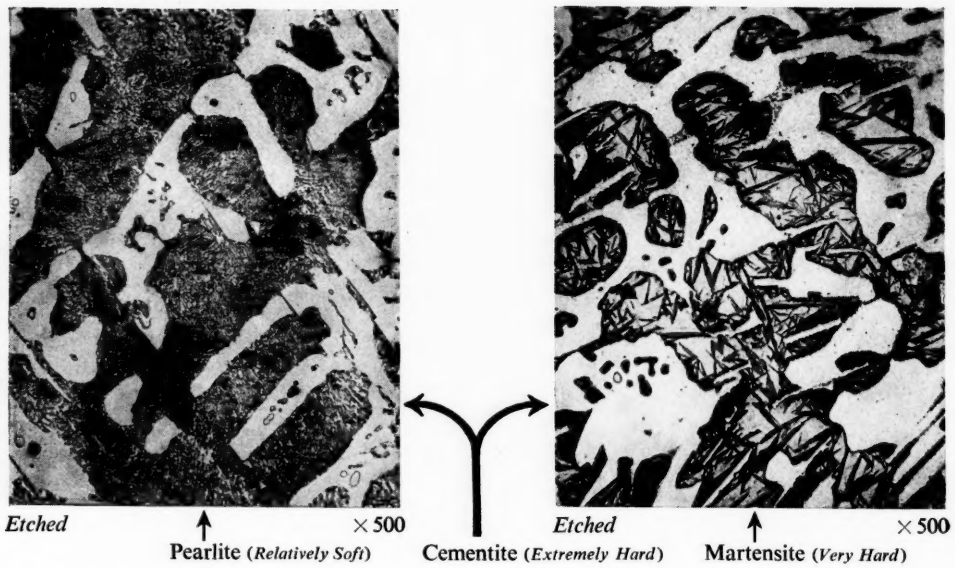

Fig. 1. Comparison of the microstructures of Unalloyed White Cast Iron and Ni-Hard
Left—White Cast Iron : 400 Brinell *Right*—Ni-Hard : 650 Brinell

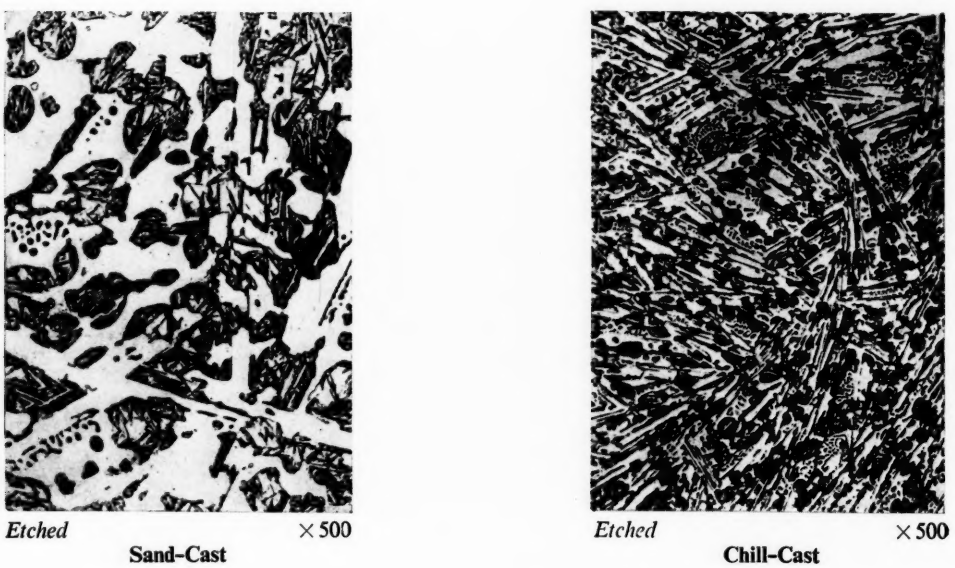

Fig. 2. Refinement in grain size produced by chilling Ni-Hard

ABSTRACTS OF CURRENT PUBLISHED INFORMATION ON NICKEL AND ITS ALLOYS

GENERAL

Fatigue of Metals: Symposium

'A Discussion on Fatigue.' *Jnl. Roy. Aeronautical Soc.*, 1953, vol. 57, Sept., pp. 559–91.

Reprint of proceedings at all-day discussion on fatigue held by the Royal Aeronautical Society in March, 1953.

H. L. COX: 'Fatigue', pp. 559–65.

Introductory paper, dealing with various modes of cracking and some of the factors affecting propagation of cracks, in materials subjected to various forms of stress.

E. R. GADD: 'Fatigue from the Metallurgist's Viewpoint', pp. 565–80.

Metallurgical factors which affect the life of components, beneficially or otherwise, are discussed, under the following headings:—structural discontinuities, grain flow, nitriding, cyaniding, carburizing, decarburization, surface hardening by heating, cold work, surface coatings, influence of temperature and of environment.

The discussion is illustrated by reference to fatigue effects in various ferrous and non-ferrous materials, as influenced by the variables mentioned. A number of the examples relate to nickel-containing steels, and, in connexion with surface coating, the effect of nickel plating on fatigue and corrosion-fatigue of steel is considered. The review is supported by a *bibliography* of 78 references.

F. M. OWNER: 'Fatigue in Engine Design', pp. 580–4.

B. E. STEPHENSON: 'Fatigue in Aircraft Design', pp. 584–8.

W. TYE: 'Summary of Discussions', pp. 589–91.

Toxicity of Metal Salts to Fish

See abstract on p. 166.

Metal Powders: Types Available

'Granular Powders for Powder-Metallurgical Applications.' *Materials and Methods*, 1953, vol. 38, Aug., pp. 127, 129, 131.

Tabular summary of metal and alloy powders now obtainable, with names of U.S. suppliers. Details are given of production method or particle shape, mesh size, and degree of purity. The list is compiled by H. B. MICHAELSON, of the Atomic Energy Division, Sylvania Electric Products, Inc.

NICKEL

Recovery of Nickel from Plating Wastes by Ion Exchange

T. J. FADGEN: 'Metal Recovery by Ion Exchange.' *Sewage and Industrial Wastes*, 1952, vol. 24, pp. 1101–7.

The bulk of wastes discharged from plants engaged in electroplating operations consist of large volumes of water containing small amounts of plating chemicals. These are usually referred to as rinse waters, and some considerable amount of research has recently been devoted to devising methods for their treatment, from the dual point of view of minimizing stream pollution and of economic recovery of usable metal and other content. This report, based on experience in the plant of General Motors Corporation, deals with laboratory studies made to determine the feasibility of applying the method of ion exchange to metal recovery from rinse waters. The basic principles of ion exchange are outlined and illustrated, and the practical usefulness of the method, for the purpose under consideration, is demonstrated by examples of its application in treating three rinse waters, containing, respectively, chromic acid, nickel, and copper. The various stages of the recovery processes are described, and treatment costs are quoted.

Solid-State Bonding of Aluminium and Nickel

See abstract on p. 170.

Colorimetric Determination of Nickel

J. M. CHILTON: 'Simultaneous Colorimetric Determination of Copper, Cobalt and Nickel as Diethyldithiocarbamates.' *Analytical Chemistry*, 1953, vol. 25, Aug., pp. 1274–5.

The fact that sodium diethyldithiocarbamate could be used for colorimetric determination of copper has been recognized since 1929, and in 1939 it was observed that cobalt and nickel also give coloured complexes with this reagent. This discovery was applied in 1946 to estimation of nickel, and in 1950 simultaneous determination of copper, nickel and cobalt was proposed, but no details were then published of the formation and separation of the metal diethyldithiocarbamates.

The method described by the present author involves formation of the carbamates at a pH of 8·5–9·0, in an aqueous solution to which pyrophosphate and citrate have been added, and subsequent extraction of the coloured complexes with carbon tetrachloride. The

procedure is particularly suitable for determination of microgram amounts of the three elements in the presence of substantial amounts of other metals. Full details of procedure are given, including means of avoiding interference by four groups of ions.

Toxicity of Metal Salts to Fish

P. DOUDOROFF and M. KATZ: 'Critical Review of the Literature on the Toxicity of Industrial Wastes and their Components to Fish. II. The Metals, as Salts.' *Sewage and Industrial Wastes*, 1953, vol. 25, July, pp. 802–39.

(The purpose and scope of this review was discussed in Part I, which dealt with alkalis, acids, and inorganic gases.)

Various metal salts are important constituents of mine effluents, brines from oil wells, and wastes of metal-processing, chemical, and other industries. Most of the metal compounds considered by the authors are the simple inorganic salts, the toxicity of which is due chiefly to the component metals. Other metal salts, such as potassium cyanide and complex cyanides, will be covered in Part III.

The survey of the metal salts is made in two sections:

(1) comparative studies of the toxicity of different metals, the factors which account for variations in their toxicity, and other matters of general interest;

(2) toxicity of individual metals: aluminium, arsenic, barium, cadmium, calcium, chromium, cobalt, copper, iron, lead, lithium, magnesium, manganese, mercury, nickel, potassium, silver, sodium, strontium, tin, zinc.

A *bibliography* of 155 items supports the review. The following references are given to work on nickel:—

Jnl. Exptl. Biol., 1939, vol. 16, pp. 425-37.
Jnl. Biol. Chem., 1924, vol. 58, pp. 671-4.
Trans. Amer. Fisheries Soc., 1915, vol. 44, pp. 120-4.
Bull. (U.S.) Bur. Fisheries, 1937, vol. 48, pp. 365-437.
Jnl. Imp. Fisheries Expt. Station (Japan), 1931, No. 2, pp. 139-93.
Zeitsch. Fischerei, 1928, vol. 26, pp. 49-61.
Gas- und Wasserfach, 1950, vol. 91, pp. 16-18.
Allgemeine Fischerei Ztg., 1951, vol. 76, No. 1, pp. 6-7; No. 2, p. 32.
Beitrage Wasser-, Abwasser- und Fischerei-Chemie, 1946, No. 1, pp. 15-23.
Jnl. Exptl. Biol., 1935, vol. 12, pp. 165-73.
Amer. Jnl. Physiol., 1904, vol. 10, pp. 290-323.
Compt. rend., Acad. Sci., 1881, vol. 93, pp. 649-51.

The survey indicates that all metal cations can be toxic to fish in rather dilute (less than 0·05 *M*) physiologically unbalanced solutions of single metal salts. In solutions prepared with natural waters containing certain dissolved minerals, and in other mixed-salt solutions, the metals are often much less toxic than in the simple solutions, because of the antagonistic action of different metal cations. It is noted, in discussion of the individual metals, that nickel and chromium have not been reported to be demonstrably toxic in any water at concentrations much less than 1 p.p.m., and that some of the comparable data in the literature reveal no pronounced difference between the toxicity of nickel and that of cobalt and manganese. Classification of nickel and chromium (together with some of the less toxic metals, such as cobalt), as metals of intermediate toxicity to fish, may, it is believed, prove justifiable in the light of additional information. Tin and iron may also belong to the same intermediate category.

ELECTRODEPOSITION AND OTHER COATING METHODS

Phosphoric-Acid Pre-Plating Treatment for Aluminium and its Alloys

B. E. BUNCE: 'Production Plating of Aluminium and its Alloys Using the Phosphoric Acid Anodizing Pre-Treatment.' *Electroplating*, 1953, vol. 6, Sept., pp. 317–22, 323.

Due to the natural oxide film formed on aluminium and its alloys, such materials do not respond satisfactorily to ordinary electroplating techniques. Various specialized pre-plating procedures have been suggested to obviate the difficulties encountered, and by means of the sodium-zincate immersion treatment, preliminary zinc plating, or preliminary anodizing of the surface, satisfactory results may consistently be obtained.

This article calls particular attention to anodizing, with specific reference to treatment with phosphoric acid, a method originally developed by the Aluminum Company of America. The present author has carried out work on several aluminium alloys, and has established optimum conditions for anodizing as a preliminary to plating with nickel, copper, or silver. For a base of high-purity aluminium the method is less suitable.

Following a record of observations made on the effect of variations in anodizing conditions, degree of adhesion obtainable between base and plating, and the general sequence of operations (including cleaning, racking, rinsing, etc.), the writer summarizes anodizing conditions found most suitable for treatment of small articles prior to electroplating. The recommendations cover treatment of aluminium alloys which are to be plated with nickel, copper or silver.

The work should be made the anode in the electrolyte at a low voltage, which is then rapidly increased to the required final value. Fairly vigorous agitation of the bath is necessary, to control the temperature at the anode surface. Periodic analysis of the electrolyte should be carried out, to maintain the desired H_3PO_4 content. A gradual build-up of aluminium takes place in the bath, but so long as the free-acid content is correct, the effect of the aluminium is not pronounced.

After the anodizing treatment, final plating may be carried out by any of the usual processes; nickel can be directly applied from both dull and bright baths, with or without a final coating of chromium.

Fatigue of Metals: Symposium

See abstract on p. 165.

Current and Metal Distribution in Electrodeposition of Nickel

J. KRONSBEIN: 'Current and Metal Distribution in Electrodeposition. III. Experimental Determination of Metal Distribution.' *Plating*, 1953, vol. 40, Aug., pp. 898–901.

The work reported was carried out as part of A.E.S. Research Project No. 11.

The data presented were obtained by measuring the metal distribution on the interior surfaces of right-angle specimens of various shank lengths and fillet radii, when plated in a specially designed shielded box, at two average current densities, in three types of electrolyte: a highly purified acid copper-sulphate bath; a Rochelle-type copper-cyanide solution, and Watts' nickel baths of conventional composition. The object of the work was to determine metal distribution under favourable conditions, in order to show the effects of fillet radius and shank length in plating on recessed surfaces.

The results show that fillet radius has very little effect on thickness of deposit in corners and along the adjacent shanks when such radius exceeds about 0·02 in. per 2 inches of shank length. Every effort should, therefore, be made by designers not to go below this figure.

Nickel and Other Anodes Used in Electrodeposition

A. C. WEST: 'Anodes for Electroplating.' *Metal Finishing*, 1953, vol. 51, Aug., pp. 66–70, 74.

This is a summary of information (based mainly on conditions in U.S.A. and Canada), relating to the types of anode commonly used in electrodeposition of copper, cadmium, cobalt and nickel. Typical analyses are given of four varieties of nickel anode in commercial supply:—cast 95–97 per cent., cast low-carbon, rolled low-carbon, and rolled depolarized grades. The characteristics of each type are described and the scope of their application is indicated.

The second part of the review is concerned with some matters which are of importance in relation to efficient use of anodes in general, e.g., length of anodes and of anode hooks.

Corrosion Tests on Electrodeposits

H. BROWN and E. W. HOOVER: 'A Corrosion Study of Various Chromium Plated Electrodeposits.' *Plating*, 1953, vol. 40, Aug., pp. 874–8; 883–5; disc., pp. 885–6.

This report describes tests carried out, from 1946 onwards, in the laboratories of Udylite Corporation, Detroit, Michigan. They originated in the observation of discrepancies between the results of salt-spray and outdoor corrosion tests on copper-nickel-chromium coatings, and the programme of the investigation was designed to secure a better understanding of the mechanism of the failure of these coatings, which are cathodic to steel, and to evaluate more clearly the respective rôles of the inherent porosity of the coatings involved and porosity electrochemically induced.

Salt-spray, humidity, and outdoor-exposure tests were made on the following types of coating:—nickel, nickel-cobalt alloy (approximately 80–20 per cent.), nickel-iron alloy (also 80–20 type), and copper. These materials were exposed, (*a*) as foil, with and without a coating of chromium, and (*b*) as electrodeposited, in various combinations, with and without chromium, on steel, brass and, in some cases, zinc bases. The behaviour of rhodium and of gold platings was also studied, with and without superimposed chromium.

The nickel foils were deposited from various baths:—Watts type, purified by activated carbon treatment and low-current-density electrolysis; all-chloride baths; semi-bright baths giving deposits containing about 0·02–0·1 per cent. carbon; fully bright baths giving deposits containing about 0·02–0·08 per cent. sulphur (as sulphide) and approximately similar percentages of carbon. The specimens also included wrought nickel sheet, and nickel electrodeposited from a Watts bath and subsequently annealed in hydrogen at 1200°–1400°F. (648°–760°C.). The copper foils were deposited from sulphate baths, and the nickel-cobalt and nickel-iron alloys from Watts-type, chloride and fluoborate baths. The cathode used for the foils was nickel sheet sufficiently passivated to ensure deposits which were non-adherent, but not blistered.

Some of the main observations made on the behaviour of the foils and coatings are summarized below:—

Foils (Salt-Spray Tests)

All the nickel foils suffered localized or pitting attack somewhat rapidly: the thin foils became mere 'screens' in the course of 100–200 hours in salt spray. The loss of weight and the number of perforations shown varied with temperature, pH, and the number and size of the droplets of salt solution condensing or falling on the surface. Copper and nickel-cobalt foils behaved in a manner similar to that of the nickel foils. Nickel-iron alloy foils showed rust spots in about six hours, but usually did not perforate so rapidly as nickel or nickel-cobalt, a difference which does not necessarily indicate that the rate of attack on the nickel-iron alloy was less, but that the pitting was of a more shallow type. The perforation of thin foils of nickel, nickel-cobalt and copper appeared to depend largely on the 'differential aeration', or oxygen-cell, effect described by U. R. EVANS.

Plated Panels (Salt-Spray, Humidity and Outdoor Tests)

For a given thickness of nickel or nickel-cobalt, the number of pores or perforations produced in the salt-spray test on plated panels was much lower than in foils of similar thickness. In 100 per cent. humidity tests at 100°F. (38°C.) the nickel-iron alloy plate protected steel as well as nickel or nickel-cobalt alloy plating of the same thickness. The fact that 0·1 mil. deposits of all these types gave good protection on the humidity tests indicates that the inherent porosity of the coatings was negligible so far as moisture was concerned, whereas chromium plating, 0·01–0·1 mil. thick, when deposited direct on the steel, did not give protection in the humidity tests, due to inherent porosity in the deposits of 0·01–0·04 mil. thick, and to stress cracks in the thicker plating. In the salt-spray test nickel or nickel-cobalt plating 0·1 mil. thick failed rapidly, due to electrochemically induced porosity, as observed with the foils, but when coatings

of the same thickness were covered by chromium about 0·01 mil. in thickness good resistance to salt spray was obtained. (This degree of protection was not, however, repeated in the outdoor tests.) The character of the protection given by this combination is discussed by the authors in relation to the passivity induced in the nickel or nickel alloy by contact with the chromic acid during plating.

Outer coatings of rhodium, deposited over nickel from an acidic sulphate bath, proved to be subject to stress-cracking and, both in salt-spray and outdoor exposure tests, accelerated corrosion. When, however, steel was plated with a composite coating consisting of nickel (1 mil.), rhodium (0·01–0·06 mil.) and finally chromium (0·01–0·02 mil.) an 'amazing' degree of protection was obtained, in both salt-spray and outdoor tests. Gold coatings, over nickel, failed to give protection in both groups of test: gold between nickel and chromium gave improved results, but the behaviour of these composite coatings was not so good as that of the nickel-rhodium-chromium group.

In outdoor-exposure tests in an industrial atmosphere nickel-cobalt and nickel-iron alloy deposits 1–1·5 mil. thick without a final chromium plating gave better protection than nickel coatings of the same thickness, but when nickel and nickel-cobalt plating 1–2 mil. thick was coated with a given thickness of chromium both gave similar results. The appearance of steel-base chromium-plated specimens having a nickel-iron underlay was inferior to that of the other specimens, but nickel-iron/chromium on brass showed, in the outdoor exposure tests, results equal to those of chromium-plated brass carrying a nickel underlay of comparable thickness. The reasons for this difference are discussed.

In the industrial atmosphere the protection obtained with 1 mil. nickel+0·04–0·08 mil. chromium was superior to that given by the same thickness of nickel with a thinner final chromium coating (0·01–0·03 mil).

With chromium deposits made direct on copper, brass or zinc, results of salt-spray and outdoor tests correlated well. In all cases the corrosion products of the underlying metals appeared through the pores and cracks of the chromium coating and undermined the brittle chromium, resulting in a tendency for it to flake off. When such combinations must be used for outdoor service, lacquers or clear-baked enamels must be superimposed to ensure additional protection.

The report is illustrated by numerous photographs showing the condition of various specimens tested, and the observations made are discussed in some detail from the theoretical aspect.

Lead-Backed Masking Tape for Use in Selective Plating

W. J. DYBER: 'Lead-Backed Masking Tape Solves Special Plating Problems.' *Automotive Industries*, 1953, vol. 108, May 15, pp. 82, 106, 110.

The writer describes the use of a lead-backed masking tape having a pressure-tight adhesive, which has been developed by Pratt and Whitney Aircraft Division of United Aircraft Corporation. Although primarily intended for use in selective hard-chromium plating, this material is being usefully employed also in plating with nickel, tin, copper, cadmium, silver and lead. An example cited relates to heavy-nickel plating of a thin-walled stainless-steel assembly for a jet engine.

Black Chromium-Alloy Electrodeposits

M. E. QUAELY: 'Black Chromium-base Electroplating.' *Plating*, 1953, vol. 40, Sept., pp. 982–5; disc., pp. 985–6.

There has for some time past been a considerable demand for black finishes possessing good adherence, resistance to heat, and black-body properties. Specific requirements have arisen in connexion with electron-tube parts, for bimetallic heater elements, and for stainless-steel parts for industrial applications. Oxide finishes have found extended use for such purposes, and phosphate-type baths have also been employed for production of black coatings. In addition, there are a number of electrochemical procedures for obtaining black finishes, and it is with this latter type that the present paper is concerned.

In view of the corrosion-resistance characteristic of chromium plating, there have been attempts to develop black finishes by electrodeposition from baths of chromic-acid base. Some degree of success has been obtained with straight-chromium electrolytes, but deposits obtainable from such baths are not so stable under high-temperature and corrosive conditions as is required in some applications. An endeavour has therefore been made to produce improved black coatings from chromium-base baths modified by (1) nickel, (2) nickel-vanadium, or (3) vanadium. To date the following results have been obtained.

(1) *Chromium–Nickel Electrolyte*

Deposits from baths containing chromic acid and nickel chloride in the ratio of 10 parts CrO_3 to 1 part $NiCl_2.6H_2O$ (26·8 oz./gal., or 200 g./L. CrO_3 with 2·68 oz./gal., or 20 g./L. $NiCl_2$), with about 0·65 fluid oz./gal. (5 mL./L.) glacial acetic acid, operated at a current density of 695–1850 amp./sq. ft. (75–200 amp./sq. dm.) gave bright silvery deposits. The deposits were hard (530 Knoop, 100-g. load), and showed good resistance to acid attack and to blistering at dull red heat, but some oxidation of the surface was observed. Treatment of these silvery deposits with concentrated hydrochloric acid for 5–30 seconds produced a 'blue-grey black' finish, which was adherent and stable. Although not jet black, the author considers that the coating is sufficiently dark to be useful in many applications.

Substitution of nickel sulphate for nickel chloride in the same type of bath resulted in flaky, non-adherent deposits. The chloride ion thus appears to be an essential ingredient of this bath in order to obtain the required quality of deposit at the high current densities employed.

(2) *Chromium–Nickel–Vanadium Electrolyte*

The possible use of vanadium in black-chromium baths was suggested by consideration of the relation between heats of formation of oxides and salts of the metallic elements, and the ease with which they can be

electrodeposited. FISCHER (*Trans. Electrochem. Soc.*, 1916, vol. 30, pp. 175–228) studied this relationship in detail, with particular reference to its application to vanadium. He concluded that since the oxides of vanadium have high heats of formation, the reducing effect produced at the cathode by electric current is insufficient to furnish the energy required to decompose a vanadic salt in aqueous solutions. In general, the energy required to decompose the salts is greater than that needed to decompose the oxides. It was therefore concluded by the present author that if a vanadium salt was added to the bath containing chromium and nickel a black deposit would result, especially since the vanadium would deposit out not as metal, but probably as an oxide. Under the conditions of electrodeposition, this oxide would be likely to be the trioxide, since any pentavalent vanadium would be reduced to trivalent vanadium at the cathode.

The bath used contained chromic acid 26·8 oz./gal. (200 g./L.), nickel chloride 2·68 oz./gal. (20 g./L.), vanadium 0·27 oz./gal. (2 g./L.), added as vanadium nitrate, glacial acetic acid 7/10 fluid oz./gal (6 mL./L.). Plating at a current density of 929 amp./sq. ft. (100 amp./sq. dm.), at 86°–95°F. (30°–35°C.) produced a uniform, adherent deposit of jet-black colour. Stability of the deposit was tested by heating a plated steel rod to redness (about 750°C.) and water-quenching. The only visible change was in colour, which became a blue-grey black: adherence was perfect. High-temperature treatment in hydrogen at 750°C., followed by further heating at 1000°C. (also in hydrogen) did not visibly affect the coating either in colour or adherence. Although it was not found possible, by X-ray diffraction methods, to determine the various constituents of the coating, it is believed that the deposit from such a bath consists of finely divided chromium and nickel metals, plus chromium oxide and vanadium oxide, probably the trioxide.

(3) *Chromium-Vanadium Electrolyte*

Successful results were also obtained with a bath containing chromic acid and vanadium salts in a ratio of 20 : 1, together with small amounts of an organic acid, such as formic, acetic, or butyric. The deposits, which were jet black, had particularly good resistance to heat. They were usually dull black, but under certain conditions (e.g., specially high temperature and current density) enamel-like glossy black coatings were obtained.

Electroless Deposition of Nickel

H. J. WEST: 'Electroless Nickel.' *Metal Finishing*, 1953, vol. 51, Sept., p. 68.

This short article describes production methods being used, and results obtained, in a plating shop working the new immersion-deposition method developed as a result of research at the National Bureau of Standards. For some account of the current status of this process, see papers referred to in *Nickel Bulletin*, 1953, vol. 26, Nos. 8–9, p. 137.

The bath formula used by the author of the note differs from that employed by the Bureau of Standards in the elimination of ammonium chloride, a modification which is claimed to result in longer effective life of the bath and production of a brighter plate. Life of the bath is of the order of eight hours: it has therefore been found more economical to use a group of smaller baths rather than one large one. Ordinary steel or rubber-lined tanks are not practicable, but in the plant described glass-lined pots of nine-gallons capacity have been found suitable: these will withstand the operating temperature (200°F. : 95°C.). Plating time is 15 minutes, which, under normal conditions, gives a coating of about 0·00015 in. thickness. Quartz-sheathed electric immersion heaters of 2,500-watt capacity are used to heat the solution: these will heat a 9-gallon pot to the required temperature in about 45 minutes.

The following formula is recommended, using either filtered commercial nickel chloride or C.P. reagent.

Nickel chloride ..	96 oz. of 5 lb. per gallon solution.
Sodium hypophosphite	12 oz.
Sodium citrate	12 oz.

Preparation of the metal to be plated is identical with that used in regular electroplating: absolute cleanliness of the part is essential. Re-plating can be carried out without stripping or buffing.

Continuous operation of a bath of this type for eight hours requires addition of a caustic-soda solution consisting of 2 oz. of a 20 per cent. solution diluted to one gallon with water. It is added by continual dropping, at the rate of about 30 drops per minute, during the plating operation. pH should preferably be maintained at 4·0, but satisfactory results may be obtained with a pH as low as 3·4. A further addition of 4 oz. each of sodium citrate and sodium hypophosphite at the end of four hours' use will help to maintain brightness. Parts plated by the electroless method must be rinsed and dried immediately after deposition: warm sawdust or methyl alcohol are suitable drying media.

Recovery of Nickel from Plating Wastes by Ion Exchange

See abstract on p. 165.

NON-FERROUS ALLOYS

Monel Stays in British Railways Locomotives

'Standard 2-6-2 Tank Locomotives, British Railways.' *Engineering*, 1953, vol. 176, Sept. 11, pp. 348–9.

British Railways are building, at their Crewe Works, 20 locomotives, the design of which is the ninth in the series of twelve standard models. This article, which describes the main features of the Class-2 2-6-2 mixed-traffic tank engines, includes a list of references (in the same journal) to descriptions of the first eight standard classes. The model of which details are now given is the smallest of the tank engines of the standard range. These have many features in common with the Class-2 2-6-0 tender locomotive built earlier in 1953, and are intended for work on the London Midland Region, on branch-line passenger services of the type at present handled by old 2-4-2 and 0-4-4T engines of pre-grouping design. In common with the

practice adopted in other types of the standard locomotives, Monel has been used for all the water-space stays in the new Class-2 2-6-2. Roof, longitudinal and transverse stays are of steel.

Contamination of Condensate in Heat Exchangers: Tests on Nickel-containing Alloys

See abstract on p. 176.

Constitution of Nickel-Titanium Alloys

A. D. MCQUILLAN: 'The Re-Investigation of a Nickel-Titanium Alloy and Observations on $\beta/(\alpha+\beta)$ Boundaries in Titanium Systems.' *Jnl. Inst. Metals*, 1953-4, vol. 82, Sept., pp. 47-8: Paper 1494.

Recent reports on investigation of the binary systems of titanium with vanadium, chromium, manganese, and nickel have shown discrepancies in the position of the $\beta/(\alpha+\beta)$ boundaries. In order to discover the reasons for the different conclusions, the present author re-examined a binary titanium alloy containing 2·4 at. per cent. of nickel. This composition was selected because of the considerable discrepancy between the temperatures at which the $\beta/(\alpha+\beta)$ boundary was found to occur by MARGOLIN, ENCE and NEILSEN (who carried out microscopical examination of quenched specimens) and by MCQUILLAN (who used the hydrogen-pressure method). It is shown that deposition of α from β can occur extremely rapidly, by a process of nucleation and growth, and it is concluded that, since in all the work reported by other investigators the experimental methods used were such as to give a delayed quench, it is likely that the extremely rapid nucleation and growth of the α phase is a factor which has not been taken into account by them.

Solid-State Bonding of Aluminium and Nickel

S. STORCHHEIM, J. L. ZAMBROW and H. H. HAUSNER: 'Solid-State Bonding of Aluminium and Nickel.' *Jnl. of Metals*, 1953, vol. 5, Sept., Sect. 1, p. 1081.

This note (on a research project still in progress) is issued as a basis for discussion at the Fall Meeting of the Institute of Metals Division of the American Institute of Mining and Metallurgical Engineers.

Solid-state bonding of aluminium and nickel has been studied as a function of temperature, pressure and time at pressure. Tensile tests and intermetallic penetration rates were used as the criteria of bonding, and metallographic examination was made of the aluminium-nickel bond interface.

NICKEL-IRON ALLOYS

Recent Developments in Ferromagnetic Materials

W. SUCKSMITH: 'Magnets and Magnetism. Recent Developments.' *Brit. Jnl. Applied Physics*, 1953, vol. 4, Sept., pp. 257-62.

An account is given of the present stage of knowledge of the subject of ferromagnetism, with particular application to ferromagnetic materials. Brief reference is made to the state of development at the beginning of the present century, and the significant phenomena and principles discovered since then are discussed. Particular attention is directed to the explanation of the magnetization curves of 'hard' (e.g., nickel-aluminium-iron-base) and 'soft' (e.g., nickel-iron-base) ferromagnetic materials.

Thermodynamic Activities in Iron-Nickel Alloys

R. A. ORIANI: 'Thermodynamic Activities in Iron-Nickel Alloys.' *Acta Metallurgica*, 1953, vol. 1, July, pp. 448-54.

Alloys of iron with nickel are of interest not only on account of their commercial importance, but also because they form nearly ideal solid solutions in the iron-rich concentration region and exhibit a superlattice in the region of the $FeNi_3$ composition. In the investigation reported in this paper the activity of iron in iron-nickel alloys was studied in a differential apparatus, by equilibrating mixtures of H_2O/H_2 gases over pure iron and over the alloys. Errors due to thermal diffusion are minimized in the design of apparatus used, and the measured activity of iron is corrected for the variation of the activity of Wüstite with ambient gas composition. (Formation of magnetite prevents investigation of nickel-rich alloys).

In the iron-rich face-centred-cubic alloys the solid solution is very nearly ideal: the activity coefficients are generally only slightly smaller than unity, the entropies of mixing are slightly larger than the ideal values, and the heats of mixing are small positive numbers.

Analysis of Nickel-Aluminium-Iron-base Alloys: Revised Standard Procedures

BRIT. STANDARDS INSTN.: 'Methods for the Analysis of Iron and Steel.' B.S. 1121. Parts 2, 4 and 5.

The revised methods referred to below have been prepared as part of the programme of work of standardizing procedures for the determination of elements in alloys of the following composition: aluminium 5-15, nickel 7-35, cobalt 10-30, copper 0·5-8, titanium 3 max., niobium and tantalum 6 max., per cent., iron balance.

Part 2. 'Nickel in Permanent Magnet Alloys.'

From a reduced solution of the alloy copper is removed as sulphide. Nickel is precipitated with dimethylglyoxime and is determined cyanometrically.

Part 4. 'Aluminium in Permanent Magnet Alloys.'

Interfering elements are removed by electrolysis, using a mercury cathode, and by precipitation with cupferron. Aluminium is precipitated with 8-hydroxyquinoline, and determined either gravimetrically or volumetrically.

Part 5. 'Copper in Permanent Magnet Alloys.'

From a reduced solution of the alloy, copper is precipitated by hydrogen sulphide, and is finally determined iodometrically.

In all cases full details of analytical equipment and procedure are given.

CONSTRUCTIONAL STEELS

Formation of Bainite in Nickel Steel

T. KO: 'The Formation of Bainite in an En 21 Steel.' *Jnl. Iron and Steel Inst.*, 1953, vol. 175, Sept., pp. 16–18.

Report on investigation of a steel containing carbon 0·33, nickel 3·47, per cent.

Bainite, formed by a shear transformation during which the coherent growth is slow, is observed in this steel up to 620°C. when the austenite has a grain size of A.S.T.M. No. 1–2. Between 620° and 540°C. the bainite is free from carbide, and different only in habit from incoherently precipitated ferrite. Between 540° and 450°C. upper bainite is formed, and below 400°C. lower bainite. The formation of α-iron from austenite, both by bainite transformation and by precipitation of ferrite, between 560° and 620°C., is theoretically examined.

Influence of Grain Size on Temper-Brittleness

L. D. JAFFE, F. L. CARR and D. C. BUFFUM: 'Effect of Grain Size upon Temper-Brittleness.' *Jnl. of Metals*, 1953, vol. 5, Sept., Sect. 2; *Trans. Amer. Inst. Mining and Metallurgical Engineers*, pp. 1147–8: T.N. 174E.

Experiments on nickel-chromium steel of S.A.E. 3140 type (nickel 1·10–1·40, chromium 0·55–0·75, per cent.), show that (confirming earlier work) increase in austenite grain size results in a rise in the temperature of transition from ductile to brittle fracture, and that the shift in transition temperature due to temper-embrittlement is greater for material of larger grain size than for finer-grain steel. Relevant literature is discussed in relation to the authors' findings.

Nickel-Silicon-Copper Rivet Steel

F. BARON and E. W. LARSON: 'Properties and Behaviour of a High-Strength Rivet Steel.'
Amer. Soc. Testing Materials, Preprint 64, June-July, 1953; 13 pp.

The use of a high-strength rivet steel in connexion with carbon, silicon, or other high-strength structural steels is, from time to time, of interest to the designer, since the substitution of high-strength rivets for rivets of carbon steel permits a reduction to be made in the number required per joint or splice, and such substitution can affect the sizes of splices or of gusset plates. Objections are, however, sometimes raised on the ground of the higher cost of the alloy-steel rivets and difficulties which are encountered in driving them. In some cases such rivets, although meeting the strength requirements laid down in A.S.T.M. and other specifications, may be deficient in ductility and in impact strength after driving. Additional objections may be raised on the score of degree of hole filling and the small values of clamping force usually obtained for such rivets, resulting in the possibility of appreciable slippage of joints at small values of load. A small clamping force may also cause lower fatigue strength of joints fastened with alloy-steel rivets, as compared with joints for which carbon-steel rivets are used.

The present paper describes the properties of a high-strength rivet steel developed by Bethlehem Steel Company, which is claimed to have certain advantages over steels of the silicon, silicon-manganese, and manganese types commonly used to meet the requirements laid down in A.S.T.M. Tentative Specification for High-Strength Rivet Steel (A 195-52T). A typical composition is given as carbon 0·06, manganese 0·50, phosphorus 0·020, sulphur 0·016, silicon 1·09, nickel 1·29, chromium 0·07, molybdenum 0·04, copper 0·68, vanadium 0·005, aluminium 0·13, per cent.

Tests reported in the paper show that rivets made from this type of steel are as ductile and as easily driven as ordinary carbon-steel rivets. At short lengths of grip the average clamping stresses of the high-strength steel rivets are about the same as those of carbon-steel rivets: at grip lengths of 2 in. and above, they are appreciably greater than the clamping stresses for carbon-steel rivets.

The behaviour, in static tension and in fatigue, of butt joints fastened with rivets of the high-strength, low-alloy steel was compared with that of joints fastened with rivets of carbon steel, and it was found that the efficiencies of both series of joints were approximately the same. The fatigue strengths of joints having a $1\frac{5}{16}$-in. length of grip were about the same in both cases, but at longer lengths of grip fatigue strengths of joints fastened with the alloy-steel rivets were greater than those of similar joints for which carbon-steel rivets had been used. It was observed that a decrease in ratio of tension to shear of riveted joints may result in a decrease in the fatigue strengths of such joints. The degree of hole filling, and the ductility of the nickel-alloy steel rivets were about the same as those of carbon-steel rivets.

Fatigue of Metals: Symposium

See abstract on p. 165.

Russian Steels

C. A. ZAPFFE: 'Russian Steels Today.' *Materials and Methods*, 1953, vol. 38, Aug., pp. 79–86.

Summary of information on compositions, properties, and uses of steels in current use in Russia in 1950–51. The information is culled mainly from sources to which reference is given in the *bibliography* appended to the review.

Four major classes cover most of the Russian steels:

I. *Structural Steels:* comprising the ordinary engineering grades; commonly used in the as-rolled condition.

II. *Machinery Steels:* (*a*) general-purpose, (*b*) special-purpose, these two covering the carbon and alloy steels employed for machine construction; used generally in the heat-treated condition.

III. *Steels for 'Instruments':* covering special carbon and alloy grades of high quality.

IV. *Special Steels:* including alloys having special electrical, magnetic, chemical, and physical properties.

Typical compositions and uses of the respective types are tabulated and discussed.

HEAT- AND CORROSION-RESISTING MATERIALS

Stainless Steel: Recent Developments and Present Position

The September 1953 issue of Sheet Metal Industries is devoted to a series of articles on production, manipulation and use of stainless-steel sheet and strip. The scope of the individual items is shown below.

C. E. HOLMSTROM: 'Stainless Steels. Their Past, Present and Future,' pp. 706–7.

Introductory notes, recalling the discovery of the corrosion-resisting properties of chromium steels of the type used for cutlery; the application of the straight-chromium steels in aero-engine exhaust valves and in the blading of steam turbines; the epoch-making introduction of the austenitic types of stainless steel, and their rapid development, including their peculiar importance in relation to the chemical industry. Attention is drawn to the likelihood of still wider use of the austenitic steels, by virtue of the heat-resisting qualities of some of the grades developed during recent years. Stainless steel is now universally accepted as one of the basic materials of industry, and by means of modern methods of production which are enabling it to be produced in an ever-widening variety of forms, and in ever-improving quality, continuous expansion of its use is assured.

'The Continuous Rolling of Stainless Steel at the New Shepcote Lane Works, Sheffield,' pp. 709–62.

The increasing popularity of stainless steel in sheet form, for the manufacture of a wide range of products, has led, during the past twenty years, to a demand which has been difficult to satisfy with the production resources available in works in the United Kingdom. Until recently it was customary in Britain to produce this material in conventional pull-over mills, but it has for some time been obvious that production on a much larger scale could be absorbed by industry. The decision was taken by Firth-Vickers Stainless Steels, Ltd., soon after the end of the war, to instal new plant for the large-scale production, on continuous lines, of stainless steel sheet, and a survey of market potentialities showed that current demands for such material could best be met by adoption of modern rolling methods which provide a product of improved quality and, ultimately, a reduction in rolling costs. Experience resulting from development along similar lines in America confirmed the wisdom of the decision to equip a completely new plant for continuous rolling.

The development has been jointly sponsored by Messrs. Firth-Vickers Stainless Steels, Ltd., and Messrs. Samuel Fox and Company, Ltd., and the outcome of the scheme is a self-contained rolling-mill plant, occupying twelve acres, and comprising hot- and cold-rolling sections and other processing equipment for continuous handling of stainless-steel strip up to approximately 1 metre wide. Although stainless steel has previously been rolled by continuous methods in Sheffield, the strip produced has been of narrow width only, and the new plant is the first in Britain in which modern rolling technique has been applied to such material in wide stock.

This article gives a highly detailed and well illustrated description of all sections of the Shepcote Lane plant, and of the operations carried out in it.

It is expected that the additional productive capacity thus made available will be sufficient not only to meet in full the current demand for stainless-steel sheet (shortage of which has recently been a serious handicap to production of many items), but will also cater adequately for the requirements of a growing range of new uses for which the stainless steels are proving pre-eminently suitable.

'New Stainless-Steel Foundry,' p. 762.

This short note draws attention to the importance of the new foundry of Messrs. A. P. V.-Paramount, Ltd., which has recently been opened at Crawley. The foundry is laid out to achieve maximum flexibility of production, and is equipped to manufacture castings of a wide variety of size and shape, in large or small quantities.

E. SMITH: 'Considerations involved in the Selection and Use of Stainless Steels,' pp. 763–6, 820.

It is emphasized that although the term 'stainless steel' has become so general, its use as a specific description of an individual material is hopelessly inadequate, in view of the many different types of corrosion-resisting steel available, each designed for particular classes of service. Over the years since the introduction of the first stainless steels, information has gradually been built up on the suitability of the various grades for resisting given corrosive conditions, and it is only by taking advantage of the experience so accumulated, and by means of trials under service or simulated-service conditions, that it is possible to arrive at the composition of stainless steel best suited for a particular purpose, and the physical condition in which it should be used. As a guide to some of the grades which have been standardized in U.K., details are given of typical compositions of austenitic steels covered by sections of British Standard En 58. Some notes on the particular characteristics of the respective grades, and of their uses, are added. Details are also tabulated of the straight-chromium stainless steels falling within B.S. En 56, and of British steels parallel to the A.I.S.I. 440B and 430 grades.

Finally, in the interests of full utilization of the properties of all the stainless steels, the writer urges that, in ordering such materials, the customer should always place before the supplier all the available information on the conditions in which the stainless-steel part will be called upon to operate.

D. H. LLOYD: 'Practical Considerations affecting the Fabrication and Mechanical Polishing of Stainless-Steel Sheet,' pp. 767–74, 784.

The avowed purpose of this article is 'to outline some of the pitfalls awaiting the unwary user who may be tempted to interpret the name 'stainless steel' too

literally.' After a short note on general principles dictating the choice of grades of stainless steel for individual applications, physical and mechanical properties characteristic of 18–8 steels are outlined, with particular reference to their forming properties and the tendency to work-hardening inherent in austenitic steels. Attention is also directed to the importance of ensuring that all tools used for forming stainless steel are well finished and are maintained free from score marks and galling, to prevent surface damage. Maintenance of the protective oxide film to which the stainless steels owe their corrosion-resistance is a further feature of importance: if the film is broken during processing, subsequent processing conditions should be such as to favour its rapid re-formation.This film, while conferring so high a degree of corrosion-resistance, inevitably introduces certain complications in connexion with lubrication, since most high-pressure lubricants depend for their efficiency on the chemical action of organic acids and a variety of derivatives of chlorine, sulphur or phosphorus. Substances applicable as lubricants for stainless steels (e.g., graphite, molybdenum disulphide, talc), chemical bond lubrication, and dry-film lubricants are briefly referred to, as is the practice of protection of pre-polished blanks during drawing operations, by kraft paper, plastic coatings, etc.

In connexion with heat-treatment of austenitic steels, the major consideration is avoidance of carbide precipitation: practical recommendations are made on this subject, and attention is also directed to the susceptibility of the scale produced on stainless steel during heat-treatment to the influence of minute quantities of contaminating substances, the presence of which can cause serious trouble. It is particularly important (*a*) to remove all traces of drawing lubricants before heat-treatment, and (*b*) to ensure that, if alkaline solutions have been used for cleaning, all alkali is removed by thorough rinsing before passing the steel for heat-treatment. An essential part of the heat-treatment plant is therefore an efficient precleaning section, and in this connexion the author gives details of typical acid pickling solutions suitable for treatment of stainless steel. Limitations inherent in this method of cleaning have encouraged the development of salt-bath pickling systems. These are of two types: the first uses a molten salt bath which chemically modifies the oxide, while the second depends on chemical reduction of the scale to loose metal powder, by sodium hydride dissolved in molten caustic soda.

The importance of final polishing is urged, since the corrosion-resistance of stainless steel is much affected by the quality of the polish. In the first operation involved in mechanical polishing it is advisable to use an efficient synthetic abrasive, to ensure rapid removal and minimum work-hardening, and care must be exercised, at all stages, to ensure adequate dissipation of heat. Residues from polishing operations should be removed by degreasing before the last hand polish. As a final operation, stainless steels are usually passivated, by immersion in a 20 per cent. v/v acid solution, after which the work must be well rinsed and dried.

H. A. HOLDEN; 'New Surface Treatment Method Facilitates the Cold-Working of Stainless and Heat-Resistant Alloys,' pp. 775–8, 819.

Methods which have been generally used for lubrication of stainless steel during cold-working may be broadly classified into the use of metallic coatings, organic coatings, and miscellaneous inorganic materials which are applied to the surface, but with which they do not combine. There has until recently been no method corresponding to the one which has proved of such practical value in facilitating the working of low- and high-carbon steels, i.e., that of 'providing the surface of an article with a thin, crystalline, coherent coating of a metallic oxide or salt, the crystals of which are in a heterogeneous crystal union with the base metal and tightly grown together with the latter', to quote the 1934 Singer patent which covers, *inter alia*, the use of phosphate coatings of the Bonderizing type.

Zinc-phosphate coatings, produced by the Bonderizing process, are extensively used in tube-drawing, wire-drawing, and deep-drawing operations on plain steels, and in cold-extrusion, but they are not applicable to stainless steels.

It has recently been possible, however, to develop a modified Bonderizing process which will produce a similar type of surface-conversion coating on stainless steel. A crystalline coating of a non-metallic organic salt (*not* an inorganic phosphate film) is formed on the surface, consisting principally of ferrous oxalate. This process, which is covered by British Patents, is designated Bonderite 'SS'. The processing solution is prepared by addition of powder chemicals to water, and operation is at 110°–120°F. (44°–50°C.). Treatment times are 5–15 minutes. As with all pre-treatment or surface-conversion processes, it is essential that grease, oil, and scale be removed before Bonderizing, and it is imperative that after pickling (whether in acid solutions or by molten-salt treatment) the work be thoroughly rinsed, to prevent carry-over of contaminants into the Bonderizing solution.

The present article summarizes some advantages found in applying the Bonderite 'SS' process to (1) tube-drawing, and (2) section- and bar-drawing.

In the latter type of work it has been found possible, by modification of the operating conditions, and the use of 'Bonderlube' lubricant, to treat sections and bars in high-nickel alloys, such as Nimonic 90, Monel and Nilo 36. To date, little work has been done on the Bonderite 'SS' process for stainless steel, but it is being successfully used for deep-drawing of components in Nimonic 75 nickel-chromium alloy, and it is anticipated that benefits found with the nickel alloy may be applicable also to stainless steel. It is reported from U.S.A. that the same process is being used in drawing of stainless-steel wire and that, as a result, faster drawing speeds, greater reductions, and improved die life have been obtained. This application is being investigated in Britain.

L. J. HUNT: 'Principles and Practice in the Spinning of Stainless Steels', pp. 779–80, 783.

The spinning of stainless steel offers many special

problems, and from its introduction some 25 years ago constant improvements in procedure have been made. The ductility of the stainless steels makes them particularly suitable for this method of working, but, due to their tendency to work-harden, more frequent annealing is required than when spinning some other materials. This short article contains general recommendations on technique and equipment.

F. A. BALL: 'Some Aspects of the Welding of the Austenitic Steels,' pp. 790–9.

The nature of the austenitic steels and the importance of maintaining their corrosion-resistance by the presence of an adequate amount of chromium evenly distributed throughout the mass are discussed in relation to the prevention of weld decay, and the properties of stabilized types of nickel-chromium steel. The characteristics of molybdenum-containing grades are specially considered, in connexion with the susceptibility to sigma formation in compositions containing free ferrite. It is, however, emphasized that the fully austenitic steels form sigma only on prolonged heating, and that this phase is not formed during a normal welding operation. Stress-relief treatment for the molybdenum-containing steels must be within the range 950°–1000°C., *not* in the sigma-formation range, 650°–900°C. Considerable attention is now being given to the effect of varying amounts of sigma on corrosion-resistance of these steels, and to methods of reducing tendency to sigma formation.

Other austenitic steels, of higher alloy content, such as those used in high-temperature equipment, also come into consideration in relation to welding properties. The author gives a table of typical compositions, and relates the composition of the steels and their welding characteristics to the well-known Schaeffler diagram, which shows weld-metal constitution as a function of nickel- and chromium-equivalent values. A review is then made of some of the outstanding differences between the welding techniques required for mild steel and austenitic steels. In this connexion, consideration is given to cracking of austenitic welds; the increasing popularity of the inert-arc process of welding (due mainly to avoidance of carbon pick-up); the application of carbon-arc welding; the potential usefulness of the atomic-hydrogen process; the use of metallic-arc welding for chemical plant and other austenitic steel parts; submerged-arc welding, and electrical-resistance welding (spot, seam and flash-butt). Attention is also directed to the newly developed inert-arc process which uses a consumable electrode of the alloy being welded (in place of the non-consumable tungsten electrode normally employed). This method, already in use in U.S.A., is considered likely to become popular also in this country.

'The Welding of Stainless and Heat Resistant Materials at the Works of Welding Technical Services, Ltd.,' pp. 805–15.

The article reviews the practice of the Company named, which has been engaged for some fifteen years exclusively in the welding of corrosion- and heat-resisting materials. The first section describes the composition and characteristics of the materials handled, of which nickel, Monel and high-temperature alloys of the Nimonic group are typical of the non-ferrous range, while the ferrous range covers all the more commonly used types of stainless steel employed in welded parts. A table shows proprietary steels made by seven British firms to B.S. specifications, with corresponding Krupp grades, and the A.I.S.I. types most nearly approximating to the British compositions. The properties of the individual types, as affecting welding, are discussed. A similar table shows the composition of some of the more important heat-resisting alloys made by five British suppliers, with notes on U.S. parallels.

Part two of this review deals with methods of welding employed at the works of Welding Technical Services, Ltd.: metallic-arc, carbon-arc, atomic-hydrogen, and oxyacetylene. The observations made relate only to the firm's own practice; no attempt is made to give a general description of the techniques, since they are already well known. The general aspects of weldability of stainless steel are considered from the point of view of metallurgical, structural and operative factors: particular attention is directed to the work of Seférian on this subject. Finally, a short review is made of some welded products typical of the output of this Company. These include air heaters, barrels for transport of corrosive and food liquids, chemical equipment of many types, furnace components, and other high-temperature equipment.

'Application of Hydraulic Power to Metal Spinning. New German Equipment,' pp. 823–4.

This article describes design and operation of heavy-duty lathes, the use of which makes possible spinning of stainless steel in much thicker gauge than has been possible when using only hand labour.

P. A. CHARLESWORTH and C. HOBSON: 'The Electrochemical Manipulation of Stainless and High-Duty Alloys,' pp. 825–32, 834, 837, 841.

The aim of this article is to show the importance of 'electropolishing' as a method of finishing high-alloy materials, emphasizing the range of operations which can be carried out by suitable variations in the anodic treatment comprized under this broad general title. Various electrolytes have been proposed for electropolishing of stainless steels: the most generally used types are all based on sulphuric-acid solutions modified by other ingredients. Current densities used vary from 50 to 250 amp. per sq. ft., driving potentials from 6 to 12 volts and temperatures of operation from 30° to 100°C. By variation within these ranges, conditions suitable for polishing almost all the stainless steels and high-nickel alloys can be established.

The article opens with notes on the type of equipment used for electropolishing and a consideration of some of the items for which this treatment has proved to be a useful method of finishing, e.g., food-handling, hospital, and surgical equipment, tubing and piping, laboratory equipment.

Although the application of electrochemical methods has thus already received some recognition for polishing, the value of this principle in solving some other manipulative problems has not yet been generally appreciated. The authors call attention to the application of the 'electropolishing' technique to such operations as deburring, shaping and tapering. Examples quoted to demonstrate such engineering applications include the deburring, shaping, and polishing of stainless steel hook frames, electro-machining of aircraft gas-turbine blades, deburring of flame-tube components, and electro-cutting of holes in high-nickel alloy nozzle castings for aircraft jet engines. It is pointed out that the electrolytic method is particularly suitable for use on components in the completely or partially fabricated state, which, due to size and/or shape, are difficult or impossible to deal with by standard engineering methods. Further commercially useful applications of electro-machining are in the sharpening of hardened and chromium-tipped machine tools and in the polishing of sheet, strip and wire.

'Stainless Steels in Industry':

'The Dairy Equipment Industry,' pp. 785–6, 789, 799.

The type of metals used in the dairy industry has been influenced, during recent years, by two major factors: (1) an increasing realization of the importance of hygiene in the handling of milk products, and (2) changes in the distributive organization, as a result of which milk is now moved over greater distances and in much larger quantities than was previously the case. This has necessitated the choice, for tanks and storage vessels, of metallic materials not only impervious to the action of milk and of sterilizing agents, but also having the properties of high thermal conductivity, strength, and malleability. Copper and iron are not resistant to the action of milk, and in addition, copper may catalyze oxidation. Tinning of either of these metals, or of steel, reduces the danger of corrosion, but its ability to do so is dependent on the efficiency of the coating; aluminium, though resistant to attack by milk, is, in pure form, too soft for large-scale use for some purposes in the dairy industry. Stainless steel of the nickel-chromium types offers all the qualities required and is generally accepted as being particularly suitable for handling all forms of dairy and food products.

Batch pasteurization is one of the most important of its applications in dairy work, and there have recently been important design developments in the direction of lighter, stronger and cheaper construction, in which the introduction of stainless-steel sheet and castings have played an important part.

F. J. STILES: 'The Brewery Industry,' pp. 800–3.

Up to the period just prior to World War II the brewing industry was operating with the traditional brewhouse plant, using copper, wood, or aluminium for the various vessels. In considering post-war activities, however, it was realized that stainless-steel construction offered many advantages, with regard to sterility of product, ease of maintenance, and appearance. The earliest large-scale introduction of such material was in fermenting departments, where experience with prototype units was so successful that it is now customary in most breweries for the fermenting vessels and fittings to be made from stainless steel, polished to a uniform degree, thus favouring sterility of the product, appearance of the plant, and easy maintenance. A further development in fermenting-vessel construction, which is finding much favour, is that of building the actual vessels in the form of shells of light-gauge stainless steel, which are encased in concrete supporting walls.

Following the adoption of stainless steel for fermenting vessels came its introduction for pipe and fittings for the mains required for the various services, and during the same period a significant step was the adoption, by the brewery industry, of the stainless-steel Paraflow heat exchanger, in place of machines in which gunmetal and copper were largely employed. The introduction of the stainless-steel exchangers has given, in the many processes in which they are employed, complete control of the respective operations, under sterile conditions.

In the handling of yeast, stainless steels have come into use for vacuum and pressure collecting vessels, and they are also used for containers for both wet and dry yeasts. The general popularity of internal steam-heated units for wort boiling, coupled with other factors, has favoured introduction of stainless steel in this section of the brewery, and a further large potential market is for casks, in which the steel is used as the sole constructional material or as a lining to wood. In all the actual and projected uses of corrosion-resisting steel in brewery equipment, the combined advantages of durability and hygiene constitute an argument which is widely recognized.

'The Catering Industry,' pp. 816–17, 842.

Over the past thirty years the considerable increase in large-scale catering and the growing appreciation of the importance of hygienic handling of food have combined to focus attention on improved design and materials. These developments have automatically directed attention to the usefulness of stainless steel, which offers the further advantage of easy upkeep at a time when labour conditions make maintenance a major factor in overheads. Kitchen and food-service equipment throughout the country bears testimony to the increasing popularity of stainless steel, and in the wholesale industries concerned with the manufacture of food and drink products its use is equally well established. Although metal-supply conditions have, in recent years, somewhat restricted such development, it may be anticipated that with return to normal availability of raw materials the use of stainless steels in the catering industry will increase still further.

'The Hospital Equipment Industry,' pp. 818–19.

The most important requirements in ideal equipment for hospital purposes are non-susceptibility to breakage, cleanliness, and ease of maintenance, ability to

remain hygienic under all conditions, and immunity from surface damage. Stainless steel meets these requirements to a unique degree, and has the added recommendation that it well withstands the mechanical abuse to which hospital equipment is liable. Typical items for which the nickel-chromium stainless steels have become standard are surgical equipment of many types, bed pans, sterilizing drums, measuring vessels, and food-handling equipment.

'Stainless Steel Rail Coaches,' p. 824.

Notes on the double-deck rail coaches in service on the Burlington Lines railroad in U.S.A. These coaches, which are of all-stainless-steel construction, seat 96 on the main floor and 52 in the upper deck. It is reported that they are proving to be a good investment, from the point of view of lowered maintenance costs, as compared with coaches of conventional type which require periodic painting. The coaches are of welded construction, fabricated by the Budd Shotweld process.

'The Textile Industry.' *ibid.*, Oct., p. 906.

Much interest has been shown in a photograph (in the September issue, p. 821) of stainless-steel equipment used in processing yarn for the Coronation carpet. The present note gives some further details.

The process of yarn dyeing is one which requires considerable care, particularly when the carpet is in solid colour, without design. If a single hank deviates even slightly from the correct shade a whole carpet may be ruined.

The yarn for the Coronation carpet was dyed in the factories of James Templeton and Company, Ltd., Glasgow, and the photograph shows the gold-coloured yarn immediately after withdrawal from a stainless-steel dye box. This box, which has a capacity of 600 lbs. of carpet yarn, was manufactured by The Longclose Engineering Company, Ltd., from $\frac{1}{8}$-in. Staybrite F.M.L.* plate, heavily reinforced, where necessary, with Staybrite steel. The tank is fitted with closed coil heating, so that live steam does not come into the actual machine, thus avoiding risk of contamination from the steam pipes in the dyehouse and dilution of the liquor during processing. The dye liquor is circulated by a Staybrite scroll-type propeller and shaft directly coupled to a totally enclosed vertical motor, mounted at the back of the machine and protected from the yarn by a stainless-steel guard which prevents the yarn from touching the motor and the motor from being contaminated with dye liquor. The equipment is fitted with a dial-type mercury-in-steel thermometer, with nickel-chromium stainless steel bulb and with flexible capillary.

Melting of Stainless Steel

H. P. RASSBACH and E. R. SAUNDERS: 'Reducing Period in Stainless Steel Melting.' *Jnl. of Metals*, 1953, vol. 5, Aug.: *Trans. Amer. Inst. Mining and Metallurgical Engineers*, pp. 1009-16: T.P. 3574C.

Much progress has been made in recent years in the theory and practice of making stainless steel. *Inter alia*, by effective utilization of oxygen for decarburization, and by addition of suitable alloying agents, it has been found possible to attain consistent production of very-low-carbon grades.

In order to facilitate economical production of these steels, the Electro Metallurgical Company has carried out extensive experimental work, the results of which have clarified a number of the complex interrelations of temperature and composition existing under decarburizing and reducing conditions. These results (already published) have been obtained, in most cases, on small experimental heats of steel, and in order to confirm their validity and significance under commercial conditions, the Company, with the co-operation of producers, has recently made a survey of stainless-steel melting practice. This paper records some of the observations made and conclusions drawn. Individual sections of the paper deal with the oxidation period and the slag-reduction period; the effect of basicity on recovery of chromium; the recovery of manganese from chromium-manganese steel slags; silicon usage in slag reduction, and estimation of slag weight. Much tabular information on individual heats is given to support the findings.

* carbon 0·07, chromium 18, nickel 9·5, molybdenum, 1·25, per cent.

Pickling of Austenitic Chromium-Nickel Steels

G. BATTA, L. SCHEEPERS, L. WINANDY and G. DALLEMAGNE: 'Pickling of Special Steels. Belgian Work on 18-8 Stainless Steel.' *Metal Treatment and Drop Forging*, 1953, vol. 20, Aug., pp. 347-52.

English version of paper published in *Revue de Métallurgie*, 1953, vol. 50, Jan., pp. 49-56; see abstract in *Nickel Bulletin*, 1953, vol. 26, No. 4, p. 68.

Descaling and Brightening of Stainless-Steel Strip

L. H. WILSON: 'Stainless Strip Descaled and Brightened Continuously.' *Steel*, 1953, vol. 133, Aug. 10, pp. 96-8.

The author describes, with diagrams, the plant and procedure used by Sharon Steel Corporation, Sharon, Pa., for treatment of chromium and chromium-nickel stainless steels. Sodium-hydride descaling is followed by electrolytic pickling, using a 3-6 per cent. nitric acid solution which was developed in the laboratories of this firm. In pickling, the work moves between suitable electrodes, and direct current of 500-1000 amperes at 12-20 volts is passed between the electrodes and the strip. The work is cathodic in one area of the tank and anodic in another. A hydraulic scrubber, using water at about 375 p.s.i. pressure, removes the smut loosened by the electropickle. After pickling, the work is hot-air dried.

Contamination of Condensate in Heat Exchangers: Tests on Nickel-containing Alloys

J. D. RISTROPH and E. B. POWELL: 'Contamination of Condensate by Heat Exchanger Tube Alloys.' *Trans. Amer. Soc. Mechanical Engineers*, 1953, vol. 75, July, pp. 729-38; disc., pp. 738-45.

Final form, with discussion, of paper abstracted in *Nickel Bulletin*, 1953, vol. 26, No. 4, pp. 61-2. A large part of the discussion was concerned with the behaviour of iron-containing cupro-nickel and of Monel.

Low-Temperature Properties of Austenitic Stainless Steels and Titanium Alloy

W. W. TYLER, L. B. NESBITT and A. C. WILSON: 'Some Low-Temperature Properties of Titanium Alloy RC-130-B and Stainless Steel.' *Jnl.of Metals*, 1953, vol. 5, Sept., Sect. 1; *Trans. Amer. Inst. Mining and Metallurgical Engineers*, pp. 104-5: T.N. 168E.

Report of determinations made in connexion with current interest in strong, non-magnetic alloys of low thermal conductivity, for use in low-temperature experiments. The titanium-base alloy contained carbon 0·14, aluminium 3·99, manganese 4·7, per cent.: the austenitic steel was the molybdenum-containing type, and some data were also obtained on a straight 18-8.

Curves show comparisons of thermal conductivity and electrical resistivity of the materials at various temperatures within the range 15° to 310°K. (−258° to +37°C.). Results of Charpy impact tests at room temperature, and at the temperatures of liquid nitrogen and liquid hydrogen are also recorded.

Spectrochemical Analysis of Nickel-base High-Temperature Alloys

W. H. TOBIN and W. O. GERBER: 'Spectrochemical Method for Analysis of a Nickel-base High-Temperature Alloy for Aluminium, Titanium, Silicon, and Manganese. Standardization by Wet Analysis. Standardization by Powdered Metal Briquets.' *Analytical Chemistry*, 1953, vol. 25, July, pp. 1128-9.

Abstract of paper presented before Society of Applied Spectroscopy, New York, May, 1953.

'A point to plane spark technique was described for the determination of manganese (0·5-2·0%), silicon (0·5-2·0%), titanium (1·3-3·0%) and aluminium (0·2-1·0%) in a nickel-base (53%) alloy containing also additions of chromium, molybdenum, cobalt, and iron. Exposure conditions for the Jaco 3·4-metre spectrograph and the General Electric Spectrosource, as well as the effects of electrode separation and sample volatility, were discussed. Analytical curves for the elements titanium, aluminium, manganese, and silicon were shown. Precision and accuracy data were also included. Several man-hours are saved as opposed to analysis by wet methods.

'Because of the scarcity of standards and the difficulties and time-consumption in the wet analysis of standards, the G.E.C. laboratory has developed a procedure for preparing standards by the use of powder metallurgy. By the use of special techniques, element retention after melting is such that added percentages can be used as final percentages. Application of this technique to the estimation of the elements tungsten, niobium, and molybdenum combination in S-816 cobalt-base high-temperature alloy; tungsten, niobium, molybdenum, silicon, aluminium, and tin in stainless steels; titanium and manganese in aluminium has been described in previous papers by the co-author. Applicability of this technique to estimation of titanium, aluminium, manganese, and silicon in the nickel-base alloy described above was discussed.'

Russian Steels

See abstract on p. 171.

Cracking in Welding of Nickel-Chromium-Molybdenum Niobium-Stabilized Steels

L. K. POOLE: 'The Incidence of Cracking in Welding Type 347 Steels.' *Welding Jnl.*, 1953, vol. 32, Aug., pp. 403S-12S.

This review summarizes information obtained from enquiries to fabricators on the incidence of cracking, supplemented by some data culled from the literature. It was carried out as a preliminary to research.

The various types of cracking which have been observed in the shops of these fabricators are discussed, and illustrated, in the following classification:—crater cracking; star cracks; hot-short cracking and microfissuring; root-cracking; base-metal cracking; cracking during stress-relief treatment.

Welding technique, as influencing occurrence of cracking of one sort or another, is considered, including discussion of the use of covered electrodes, inert-arc welding, and submerged-arc welding.

Based on the information thus collated, the author outlines research which he considers is urgently required:—the development of laboratory tests which reproduce production difficulties; study of the effect of restraint and of joint design; of welding techniques and the influence of variants inherent in them; of the effect of stress-relieving on mechanical properties, and of cracking during stress-relief; of base-metal characteristics; of the influence of variations in electrodes; of the effect of service temperatures, and of thermal shock, and of the influence of welding together dissimilar metallic materials.

Welding of Austenitic Nickel-Chromium Steels

F. H. KEATING: 'The Welding of Equipment in Chromium-Nickel Austenitic Steel.' *Welder*, 1953, vol. 22, Apr.-June, pp. 61-9.

The paper opens with brief reference to early difficulties due to chromium-carbide precipitation, and to methods adopted for stabilization. This is followed by more detailed discussion of three major problems associated with the use of stabilizing elements:—development of sigma phase; significant reduction of corrosion-resistance in certain conditions; development of low resistance to impact at sub-zero temperatures, particularly in the weld metal.

Against this background, the production of welded equipment in austenitic steel is considered from the point of view of the varieties of composition encountered, welding processes suitable for use on such materials (including selection of filler material); forming and preparation of the materials for welding; standards required in the actual welding operations; heat-treatment of welded joints; finishing treatments for welded parts.

Throughout the review it is emphasized that the materials discussed are of a grade involving considerable capital outlay, and that serious loss is involved in the failure of even a single item of equipment, which may cause interruption of the work of a whole plant. It is therefore imperative that the characteristics of the individual materials should be well understood and that, at all stages of manufacture, the utmost care should be exercized.

Metallic Arc Welding of Austenitic Steels

M. C. T. BYSTRAM: 'Developments in Metallic Arc Welding of Corrosion- and Heat-Resisting Alloys.' *Welding and Metal Fabrication*, 1953, vol. 21, Sept., pp. 325–6.

A general review, including consideration of methods of stabilization, use of austenitic electrodes, hot-cracking of multi-layer welds and the use of 'ferrite-controlled' electrodes; the advantages of welds comprising layers of different composition, varied in sequence according to the conditions of service to which the part will be exposed; possible lines of development in welded construction.

Testing of Welded Austenitic Nickel-Chromium Steel

'Disintegration Test for Welded Austenitic Chromium-Nickel Corrosion-Resisting Steel: Proposals prepared by Commission IX, 'Weldability', of the International Institute of Welding.' *Trans. Inst. Welding*, 1953, vol. 16, June, pp. 80–1.

Although the Hatfield or Strauss test, as carried out according to A.S.T.M. A-240 and other specifications, is widely accepted as giving reliable information on the susceptibility of a welded stainless steel to intercrystalline corrosion, it is considered to be, in some cases, too severe a test, since the heat-treatment laid down in the specification is quite different from that to which welded parts will be subjected in moderate service. The alternative procedures proposed in this note are suggested as approximating more closely to service conditions. Diagrams illustrate the welding procedure for the test pieces, and the equipment to be used in applying the copper-sulphate or nitric-acid tests and in making the bend test.

Corrigendum

Nickel Bulletin, August-September, 1953; p. 158, Table I. Contained Alloy: in second column, for '1%' read '10%'.

PATENTS

Electrolytic Separation of Nickel from Cobalt

In a process for the separation of nickel from cobalt (both being contained in the form of salts in a solution), the solution is rendered acid and is subjected to electrolysis at a temperature between 50°C. and boiling point, using a mercury cathode. The ratio of nickel to cobalt in the solution diminishes as electrolysis proceeds, and eventually substantially all the nickel is deposited on the mercury cathode, forming an amalgam, which is separated from the solution containing the cobalt. The nickel is then separated from the cobalt remaining in the amalgam by electrolizing, making the amalgam the anode.

M. DE MERRE. *Brit. Pat.* 691,300.

Heat-Treatment of Cathode Anodes

Electrolytic nickel cathode sheets are heat-treated, preferably at 2100°–2500°F. (1150°–1370°C.), to transform the normal columnar crystal structure to one of equiaxed grains of average size not less than about 0·090 mm. Material treated in this way is suitable for use as anodes in electrodeposition of nickel.

HANSON-VAN WINKLE-MUNNING CO. *Brit. Pat.* 695,929.

Chemical Brightening of Nickel and Nickel Alloys

The surfaces of nickel and nickel-base alloys are chemically brightened by immersion in a solution containing 45–60 per cent. orthophosphoric acid, 15–25 per cent. sulphuric acid, 8–15 per cent. nitric acid, and 10–20 per cent. of water, all percentages by weight. The treatment is carried out at a temperature above 65°C.

ALUMINUM CO. OF AMERICA, assignee of W. G. ZELLEY. *U.S.Pat.* 2,638,410.

Reactivation of Nickel Catalysts

Exhausted nickel hydrogenation catalysts are reactivated by treatment, while suspended in a suitable liquid medium, with hydrogen, under pressure, at 80°–150°C.

SCHWEIZERISCHE SPRENGSTOFF-FABRIK, A.G. *Brit. Pat.* 692,300.

Production of Porous Accumulator Plates and Filters

Porous bodies sintered from metal powders (e.g., accumulator plates or filters made from carbonyl-nickel powder) are strengthened by local pressure during or after sintering, producing compact coherent parts having a net-like structure. The body is then sintered a second time, preferably at a higher temperature than that used in the first operation. The depressions in the plates or filters may be filled with metal powder and the whole again re-sintered.

BADISCHE ANILIN- UND SODA-FABRIK. *Brit. Pat.*, 694,384.

Porous electrodes for alkaline accumulators are made by sintering, at 800°–1050°C., an uncompacted mass of a metal powder made by decomposition of a mixture of nickel and iron carbonyls or by chemical precipitation of oxides from a mixed nickel- and iron-salt solution, and subsequent reduction.

STÉ. DES ACCUMULATEURS FIXES ET DE TRACTION (Inventor, P. A. C. JACQUIER). *U.S. Pat.* 2,646,457.

Electrodeposition of Nickel Powder

Nickel powder of fine particle size is electrodeposited from a bath containing a soluble nickel compound, a soluble ammonium compound, and a soluble compound of an alkali or alkaline-earth metal. The preferred electrolyte comprises nickel chloride, ammonium chloride and sodium chloride, in specified proportions. Two types of anode are employed, the main type being one or more anodes of nickel or nickel-containing material, which serve to replenish the bath in nickel, and the other (secondary) anodes being of a current-carrying material which is insoluble in the electrolyte. Stainless-steel cathodes are employed. Full details are given of equipment and technique,

and typical plating cycles and resulting products are described.

S. A. MAYPER, assignor to UNITED STATES OF AMERICA as represented by U.S. ATOMIC ENERGY COMMISSION. *U.S. Pat.* 2,625,507.

Production of Nickel Hydroxide

Very pure nickel or cobalt hydroxide, free from adsorbed impurities and of very small crystal size, is made by precipitating an aqueous solution of a nickel or cobalt salt with a water-soluble hydroxide (maintaining the pH of the solution above 12·5), and treating the resulting product with an anhydrous organic solvent which will dissolve the water-soluble hydroxide. Suitable solvents are: aliphatic alcohols with 1-5 carbon atoms, or their ethers; furanes, hydrofuranes, and ketones with less than 6 carbon atoms.

MOND NICKEL CO., LTD. *Brit. Pat.* 696,614.

Nickel Plating by Decomposition of Nickel Carbonyl

A fine spray of a thermally decomposable compound of a plating metal is blown, in a stream of inert gas, onto the article to be plated, which is heated to the decomposition temperature of the compound. The process may be applied by use of the carbonyls, carbonyl halides, nitrosyls, hydrides, metallic alkyls, and similar compounds of nickel, iron, chromium, cobalt and other metals. Examples include plating by means of nickel carbonyl.

C. F. DAVIS and H. G. BELITZ. assignors to COMMONWEALTH ENGINEERING CO., *U.S. Pat.* 2,619,433.

Electrodeposition of Nickel-Cobalt Alloy on Recording Tape

A thin layer of magnetizable nickel-cobalt alloy is electrolytically deposited on the surface of a magnetic recording tape or wire, under closely specified conditions.

P. P. ZAPPONI. assignor to BRUSH DEVELOPMENT CO., *U.S. Pat.* 2,619,454.

Electrodeposition of Nickel-Phosphorus Alloys

Nickel-phosphorus and cobalt-phosphorus alloys are electrodeposited from solutions containing sulphates and chlorides of nickel or cobalt, and phosphoric and phosphorous acid. The solutions are maintained at a pH of 0·5-2·0.

A. BRENNER, D. E. COUCH and E. K. WILLIAMS, assignors to U.S. SECRETARY OF THE ARMY, *U.S. Pat.* 2,643,221.

Nickel-Phosphorus Alloy Coatings

For production of a coating of nickel-phosphorus alloy on ferrous materials the preferred method of application is to paint on a suspension of finely divided NiO and $(NH_4)\,H_2PO_4$ and heat the coated material to 1600°-1800°F. (870°-980°C.) in hydrogen.

G. J. HORVITZ, assignor to G. B. JACK. *U.S. Pat.* 2,633,631.

Nickel Alloys in Bimetallic Strip

The low-expansion part of a bimetallic strip is made from an alloy containing cobalt 15-25, nickel 20-35, per cent., balance iron, and the high-expansion part from a material including nickel and/or copper, the nickel+copper being at least 15 per cent. Examples of the high-expansion alloy composition are given as: (1) nickel 15, manganese 7, per cent., iron balance; (2) nickel 10, manganese 74, copper 15, per cent.; (3) pure nickel; (4) pure copper.

STÉ. ANON. DE COMMENTRY FOURCHAMBAULT ET DECAZEVILLE. *Brit. Pat.* 697,617 (corresponding to *French Pat.* 996,105).

Binders for Sintered Tungsten Bodies

A sintered body of high specific gravity consists of tungsten and a binder metal of lower melting point which contains at least one metal of the iron group and 5-50 per cent. of molybdenum. The binder may also contain up to 30 per cent. of manganese. Suitable compositions are quoted (parts by weight) as:—(*a*) molybdenum 1, nickel 6, iron 1, manganese 2; (*b*) molybdenum 1, nickel 3, iron 1; (*c*) molybdenum 3, nickel 6, cobalt 1; (*d*) molybdenum 4·5, nickel 5·5.

METRO-CUTANIT, LTD. *Brit. Pat.* 693,815.

Anisotropic Nickel-Alloy Magnets

Anisotropic permanent magnets having a massive crystal structure are made by compacting and sintering at 1200°-1400°C. a mixture containing powdered iron, nickel, cobalt and aluminium. The aluminium must be present as an alloy with a metal of the iron group, and no liquid phase must exist at the sintering temperature. An aluminium-cobalt alloy is preferred. The preferred composition of the finished magnet is cobalt 16-30, nickel 12-20, aluminium 6-11, copper up to 3, per cent., balance iron. $BH_{max.}$ of 5×10^6 or above is claimed.

R. J. STUDDERS and D. G. EBELING., assignors to GENERAL ELECTRIC CO. (U.S.A.) *U.S. Pat.* 2,617,723 (similar to *Canad. Pat.* 495,720).

Horological Springs

Driving springs for time-piece mechanisms and other uses are made from an age-hardenable alloy of the following composition:—cobalt 20-45, nickel 20-35, iron 10-25, titanium 1-5, niobium 1-5, per cent. Niobium+titanium is specified as 3-7 per cent. Up to 10 per cent. tungsten, 10 per cent. molybdenum, 20 per cent. chromium and 5 per cent. tantalum may also be present. Heat-treatment is specified. Springs of this type are characterized by good resistance to oxidation and to fatigue.

E. DUBOIS, B. E. SIEGRIST and C. H. WAKKER. *Brit. Pat.* 691,148.

Heat-Treatment of Nickel-Alloy Steel for Bearings

A steel suitable for bearings contains carbon 0·05-0·3, nickel 1-4, chromium 1-3, molybdenum 2-6, manganese 0·2-1·0, silicon 0·1-0·75, per cent., balance iron. It is carburized at 1650°-1800°F. (900°-980°C.), air- or liquid-cooled, and repeatedly reheated to 600°-1200°F. (315°-650°C.), and cooled to

room temperature, to effect gradual conversion of austenite to martensite, thus avoiding excessive changes in stress.

O. W. McMULLAN, assignor to BOWER ROLLER BEARING CO. *U.S. Pat.* 2,624,687.

Nickel-Alloy Die Steel

Air-hardening steel for forging dies contains (by weight) carbon 0·3–0·4, manganese 1·5–2·5, silicon 1·25–2·5, chromium 3–4, tungsten 0·75–1·5, nickel 1–2, per cent., balance iron. The steel is characterized by high impact strength, good wear-resistance and hot hardness; it also shows good resistance to thermal cracking. A preferred composition is given.

BRITISH THOMSON-HOUSTON CO., LTD. *Brit. Pat.* 691,518.

Mechanical and Thermal Treatment of Boron-containing Nickel-Chromium Steels

Creep-resisting austenitic steel contains carbon 0·01–0·50, chromium 15–25, nickel 10–35, boron 0·01–0·30 per cent., together with one or more of the elements titanium, niobium, tantalum, zirconium, in total amount sufficient to combine with the carbon and stabilize the steel. Optionally one or more of the following elements may be present:—tungsten, molybdenum, vanadium, silicon (up to 6 per cent. in all), cobalt 0–30, nitrogen 0–0·30, per cent. The steels are hot-worked (preferably by forging) at a temperature below 1180°C., rapidly cooled from 1100°–1170°C., and annealed for several hours at a temperature below 800°C.

DEUTSCHE EDELSTAHLWERKE, A.G. *Brit. Pat.* 691,811.

Heat-Resisting Alloy Suitable for Precision Casting

The following composition is claimed as suitable for a precision-cast creep-resistant alloy:—carbon 0–0·25, titanium 1·50–3, manganese 0–1, aluminium 1–4, silicon 0–1, boron 0·01–0·5, chromium 13–17, iron 8–12, molybdenum 4–6, per cent., balance nickel.

GENERAL MOTORS CORPN., assignee of S. R. CALLAWAY and F. J. WEBBERE. *Brit. Pat.* 697,589.

Nickel-Chromium-Manganese Electrical-Resistance Alloys

An alloy for electrical resistor elements contains nickel 50–70, chromium 8–28 per cent., balance manganese (15–36 per cent.). The resistivity of the alloy is improved by solution treatment at 1500°–2100°F. (815°–1150°C.) for 2 seconds to 100 hours, followed by ageing at 600°–1200°F. (315°–650°C.) for a quarter of an hour to 100 hours. An alloy containing nickel 60, chromium 10, manganese 30 per cent. is specifically referred to.

J. H. JACKSON and C. T. GREENIDGE, assignors to C. O. JELLIFF MANUFACTURING CORPN. *U.S. Pat.* 2,628,900.

Dental Casting Alloy

An alloy for dentures, claimed to be characterized by good castability, resistance to corrosion, and low melting point, is of the following composition:—carbon 0·05–0·15, manganese 0·70–0·90, silicon 1·20–1·60, chromium 17·5–19·5, tungsten 9·0–10·0, nickel 29·0–31·0, cobalt 23·0–25·0, tantalum 0·6–0·7, copper 10·0–12·0, aluminium 0·8–1·0, per cent., balance iron. The function of each of the elements present is discussed.

S. LOW. *U.S. Pat.* 2,636,818.

Corrosion-Resisting Non-Magnetic Alloy Steels

The following limits are laid down for high-alloy non-magnetic steels:—chromium, nickel, copper and molybdenum 6–20 per cent. each, balance iron. The proviso is that chromium+nickel+copper+molybdenum shall be less than 50 per cent. Preferred examples are cited.

K. SPITZ. *U.S. Pat.* 2,633,420.

Gas Welding of Stainless Steel

Carburization of chromium-nickel stainless steel during oxy-hydrocarbon gas welding is avoided by mixing with the hydrocarbon gas a combustible sulphur compound.

P. S. VILES, assignor to STANDARD OIL DEVELOPMENT CO. *U.S. Pat.* 2,626,459.

Impregnation of Stainless-Steel Compacts with Stabilizing Elements

Sintered articles made from austenitic stainless steel powder which are to be welded are stabilized by incorporation with one or more carbide-formers. Titanium hydride is the preferred medium of addition. The hydride, on sintering of the compact, liberates hydrogen, leaving the titanium metal in a chemically active form for reacting with the chromium carbide, which is at that stage uniformly dispersed throughout the mass. An exchange reaction takes place between the titanium carbide, liberating chromium and leaving titanium carbide, which does not diffuse rapidly during the welding operation. Other stabilizers which may be used are low-carbon chromium-titanium, titanium, zirconium hydride, niobium, and tantalum.

METAL AND PLASTIC COMPACTS, LTD. (Inventor: D. A. OLIVER). *Brit. Pat.* 694,326.

Attention is drawn to the fact that many of the names of materials mentioned in The Nickel Bulletin are *Registered Trade Marks.*

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